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Chilling Injury of Cured and Noncured Porto Rico Sweetpotatoes

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CURING AND OTHER FACTORS AFFECTING CHILLING INJURY

Chilling, which results when temperatures in the storage house drop too low, is responsible for physiological changes that bring about a break-down of sweetpotatoes and make them particularly subject to spoilage by various storage rots. Limited observations had indicated that chilling injury was less in roots properly cured by artificial heat before storage than in noncured ones.

To help operators of sweetpotato storage houses reduce or prevent chilling injury the experiments described in this circular were set up with Porto Rico sweetpotatoes under controlled conditions at Meridian, Miss. The influences of proper curing, of the temperature and the duration of the exposure, and of the period between harvesting and exposure to low temperatures on the severity of chilling injury of Porto Rico sweetpotatoes were studied during three seasons. The results indicated that cured roots, when exposed to low temperatures, decayed less than noncured ones; that the color of the raw flesh of cured ones, which is correlated with the eating quality, was better at all tested temperatures and durations of exposure; that decay of noncured roots held for 1 to 3 months between harvest and exposure to low temperature was in general greater than that of cured roots but less than that of those exposed to low temperatures immediately after harvest; that the flavor after baking of roots held for 1 to 3 months before exposure was in general better than that of those exposed immediately after harvest; that at controlled temperatures above 50° F. cured roots decayed less than noncured ones; and that setting the thermostat of the storage house for a minimum temperature of 50° produced just as good results

as setting it for 55°. The results of the tests are summarized in more detail as follows.

Injury to the quality of freshly harvested noncured Porto Rico sweetpotatoes was evident after they had been held 2 days at 32° F., 4 days at 40°, or 10 to 21 days at 50°. Slightly longer exposures at 32° and 40° were necessary to produce injury in cured sweetpotatoes; the latter were not impaired in quality by exposures to 50° for 30 days or less.

Decay during storage was increased in noncured sweetpotatoes by holding periods of 4 to 10 days at 32° to 50° F. Somewhat longer exposures were necessary to increase decay of cured sweetpotatoes held at 32° and 40°. Holding cured sweetpotatoes at 50° did not influence the development of decay.

A delay of 30 days or longer between harvesting the roots and subjecting them to low temperatures prevented much of the loss from decay and injury to quality which otherwise occurred in noncured sweetpotatoes.

Noncured sweetpotatoes stored for 4 to 4½ months at a constant temperature of 50° F. suffered practically 100-percent loss from decay. The loss was somewhat less in storage at 55° and still less in storage at 60°. Even at that temperature, however, there was significantly more decay than in comparable noncured sweetpotatoes stored in a sweetpotato storage house in which the temperature fluctuated with the outside temperature but did not drop below 50° and averaged 57.8°. Although cured sweetpotatoes held at constant temperatures of 50° and higher did not develop significantly more decay than comparable ones held in the storage house, their culinary quality was adversely affected when held at 50°.

Decay, weight loss, and quality of cured and noncured sweetpotatoes held in storage rooms of a sweetpotato storage house that were kept from going below temperatures of 50° and 55° F. were practically the same, indicating that it is not necessary to maintain a minimum temperature higher than 50° F. in a sweetpotato storage house for temperature conditions such as prevail at Meridian, Miss.

PRACTICES RECOMMENDED FOR AVOIDING CHILLING INJURY

- (1) Wherever possible cure sweetpotatoes for 10 to 14 days—
 - (a) At a temperature of 80° to 85° F.
 - (b) At a relative humidity of 85 to 90 percent.
- (2) Store cured sweetpotatoes—
 - (a) At temperatures that never go below 50° F.
 - (b) At a relative humidity of 80 to 85 percent.
- (3) Where curing is not possible, before shipping roots keep them for at least 30 days where they will not be exposed to temperatures below 50°.

MATERIALS AND GENERAL METHODS

The experiments reported in this circular were conducted during three seasons, 1941-44, at the U. S. Horticultural Field Station, Meridian, Miss., with Porto Rico sweetpotatoes grown in that vicinity.

Both cured and noncured sweetpotatoes were used. The curing was done in an electrically heated, thermostatically controlled

sweetpotato storage room in which the relative humidity was rather high and the thermostat was set to maintain an average temperature of about 85° F. The length of the curing period was 10 to 12 days. The noncured sweetpotatoes were held in an unheated room in which no attempt was made to control the relative humidity during the period when comparable roots were being cured. During the curing period the average temperature was 67° in the unheated room and 83° in the heated one. In the unheated room the average relative humidity was 71 percent and in the heated one it was 77 percent. Although the relative humidity in the curing room was slightly less than that usually recommended, that of the air immediately surrounding the room was undoubtedly somewhat higher and was probably at or near the optimum for curing.¹

The average relative humidity in the various cold-storage rooms in which sweetpotatoes were held to determine experimentally the influence of constant temperatures on the roots ranged from 71.5 to 76.5 percent.

Quality was determined by baking 5 or 10 medium-sized roots for 1 hour and 20 minutes at 400° F. Ratings were made on the color of the flesh before and after baking and on the flavor after baking. The color ratings were based on freedom from discoloration and the flavor ratings on the presence of desirable flavors and the lack of undesirable ones. There was a very close correlation between color of raw flesh and culinary quality. Chilling affected both adversely.

The differences required for significance were determined by the analysis-of-variance method.

COMPARATIVE INJURY OF CURED AND NONCURED ROOTS

EXPOSURES IMMEDIATELY AFTER HARVESTING OR CURING

Noncured sweetpotatoes were subjected to temperatures of 32°, 40°, and 50° F. immediately after harvesting and cured sweetpotatoes to the same temperatures immediately after curing for the periods indicated in table 1. These temperatures were thermostatically controlled and ranged from 1½° below to 1½° above the desired temperature. After the exposures indicated in table 1, the sweetpotatoes were removed to a room in a sweetpotato storage house in which the temperature was not allowed to drop below 50° and much of the time was above 55°. The sweetpotatoes were held in this storage until 4½ months after harvesting. The values for percentage of decay given in table 1 are the averages of three ½-bushel lots for each treatment. One of these lots was handled very carefully to prevent mechanical injury of the roots, another was handled roughly to produce considerable skinning and bruising, and the third was handled in a way that approximated the methods generally used by farmers and gave mechanical injuries intermediate between the other two methods.

The relative effects of the various temperature treatments were the same on all lots, although, as would be expected, the lot which was handled roughly had much more decay than either of the

¹ LUTZ, J. M. FACTORS INFLUENCING THE RELATIVE HUMIDITY OF THE AIR IMMEDIATELY SURROUNDING SWEET POTATOES DURING CURING. Amer. Soc. Hort. Sci. Proc. 43: 255-258. 1943.

other two. Cured sweetpotatoes exposed for 10 days or longer at 32° F. or for 21 days at 40° had a significantly higher percentage of decay when the roots were examined 4½ months after harvesting than the roots which were not exposed to low temperature (table 1). No influence on development of decay was apparent in cured sweetpotatoes held at 50° before regular storage in the sweetpotato house. With noncured sweetpotatoes an exposure of 4 days or more at 32° or 10 days or more at 40° or 50° resulted in a significantly increased percentage of decay as compared with the check treatment.

TABLE 1.—*Effect of duration and temperature of exposure on decay and rating for color of raw flesh of Porto Rico sweetpotatoes, 1942*

[Results 4½ months after harvest. Ratings for color of raw flesh: 1, Excellent; 2, good; 3, fair; 4, poor; 5, very poor]

Duration of exposure (days)	Roots decayed after exposure to indicated temperature (° F.) ¹						Rating for color of raw flesh of roots after exposure to indicated temperature (° F.) ¹					
	32		40		50		32		40		50	
	Cured	Non-cured	Cured	Non-cured	Cured	Non-cured	Cured	Non-cured	Cured	Non-cured	Cured	Non-cured
0 ²	Pct. 4.8	Pct. 7.8	Pct. 4.8	Pct. 7.8	Pct. 4.8	Pct. 7.8	1.2	1.2	1.2	1.2	1.2	1.2
1.....	1.8	5.9					1.0	1.2				
2.....	1.6	13.5	.9	2.4			1.6	1.8	1.0	1.8		
4.....	3.3	24.6	.0	10.9	2.4	12.1	1.8	2.8	1.5	3.2		1.2
7.....	6.8	55.4	.8	23.3	1.7	15.0	2.4		1.8	2.5	1.2	1.8
10.....	24.0	100	1.7	27.3	5.2	30.6	4.9		2.6			1.8
14.....	93.8	100	10.9	43.6	2.4	28.3			3.5		1.1	2.0
21.....			48.7	100	.0	51.5						2.8
30.....					2.4	73.6					1.1	

¹ Differences required for significance between treatments: For decay, 16.2 percent; for ratings for color of raw flesh, 0.6.

² Not subjected to low temperatures; stored in a sweetpotato storage house continuously at 50° to 72° (average 57.7°).

These results are in agreement with those obtained by Harter, Weimer, and Adams,² who reported that a number of fungi caused decay in sweetpotatoes at temperatures lower than those at which sweetpotatoes are usually stored. Lauritzen,³ working with varieties of the Jersey type, also found that at temperatures below 9° C. (48.2° F.) sweetpotatoes are susceptible to infection which does not occur at temperatures above this.

The influence of low temperature on color of raw flesh is also shown in table 1. The results are similar to those on decay, except that a shorter exposure to low temperatures affected color. The effects of the low temperatures on color and flavor of baked sweetpotatoes were similar to those on raw-flesh color, but the exposure periods that produced injury differed somewhat (table 2).

Lauritzen³ found that besides being susceptible to invasion by decay organisms, sweetpotatoes show internal browning at low temperatures. In some cases the chilling effects were not noticeable until the roots were later subjected to 50° F. or higher temperatures. Lauritzen concluded that exposure to temperatures below 9.5° C. (49.1° F.) for less than 10 days would not be injurious.

² HARTER, L. L., WEIMER, J. L., and ADAMS, J. M. R. SWEET-POTATO STORAGE-ROTS. Jour. Agr. Res. 15: 337-368, illus. 1918.

³ LAURITZEN, J. I. SOME EFFECTS OF CHILLING TEMPERATURES ON SWEETPOTATOES. Jour. Agr. Res. 42: 617-627, illus. 1931.

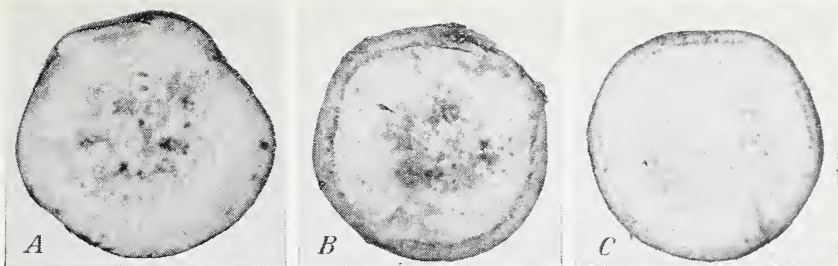


FIGURE 1.—Cross section of chilled uncooked sweetpotatoes 4½ months after harvest: A, Noncured and held at 32° F. for 2 days; B, noncured and held at 40° for 7 days; C, cured and held at 40° for 7 days. Note the greater darkening of the noncured roots.

The results reported here show that, under many conditions of exposure to low temperatures, increased decay or other evidences of chilling injury to sweetpotatoes are possible in a much shorter period than the 10 days suggested by Lauritzen,⁴ since noncured sweetpotatoes were injured by 2 days' exposure to 32° F. (fig. 1, A) or 4 days' exposure to 40°.

TABLE 2.—Periods of exposure at different temperatures that produced significant differences in decay, color, and flavor in nonexposed and exposed Porto Rico sweetpotatoes, 1942

[Results 4½ months after harvest]

Factor affected by exposure	Length of period ¹ of exposure to indicated temperature (° F.) significantly affecting roots					
	32		40		50	
	Cured	Noncured	Cured	Noncured	Cured	Noncured
	Days	Days	Days	Days	Days	Days
Decay.....	10	4	21	10	(?)	10
Color of raw flesh.....	4	2	10	4	(?)	10
Color of baked flesh.....	4	2	4	4	(?)	21
Flavor.....	4	2	4	4	(?)	14

¹ Periods were determined before rating values were rounded off.

² No different from nonexposed roots after 30 days' exposure.

Lutz⁵ found that sweetpotatoes kept in a sweetpotato storage house in which the temperatures were allowed to drop to 40° F. or lower were injured and that proper curing reduced the losses from decay which occurred at low temperatures or followed exposure to them. Kimbrough and Bell⁶ stated that exposure of Porto Rico sweetpotatoes for 1 week to temperatures of 40° or lower was injurious. They reported lack of latex on cut surfaces as well as discoloration in injured roots.

Artschwager and Starrett⁷ showed that suberization and wound-periderm formation on cut surfaces of sweetpotatoes are favored by high relative humidity and temperatures in the range from 85° to 90° F. As shown herein, these temperatures and humidity conditions during curing are also effective in preventing

⁴ See footnote 3, p. 4.

⁵ LUTZ, J. M. CURING AND STORAGE METHODS IN RELATION TO QUALITY OF PORTO RICO SWEETPOTATOES. U. S. Dept. Agr. Cir. 699, 12 pp., illus. 1944.

⁶ KIMBROUGH, W. D., and BELL, M. F. INTERNAL BREAKDOWN OF SWEETPOTATOES DUE TO EXPOSURE TO COLD. La. Agr. Expt. Sta. Bul. 354, 9 pp., illus. 1942.

⁷ ARTSCHWAGER, E., and STARRETT, R. C. SUBERIZATION AND WOUND-PERIDERM FORMATION IN SWEETPOTATO AND GLADIOLUS AS AFFECTED BY TEMPERATURE AND RELATIVE HUMIDITY. Jour. Agr. Res. 43: 353-364, illus. 1931.

some of the injury which otherwise occurs in sweetpotatoes when they are subjected to low temperatures.

In the present studies it was found that the period that sweetpotatoes can be held in storage depends on whether they are cured or not when exposed (fig. 1, *B* and *C*), as well as on the temperature to which they are exposed before or during storage. Cured sweetpotatoes can tolerate lower temperatures than noncured ones. As would be expected, the lowest temperatures produced the most severe injury. Even 50° F., which is generally considered a satisfactory temperature for storing cured sweetpotatoes, produced changes in 10 days in noncured sweetpotatoes that showed up as injury later. Cured sweetpotatoes exposed 30 days at this temperature showed no subsequent damage.

TABLE 3.—*Effect of duration and temperature of exposure and period between harvest and exposure on decay and flavor rating after baking of Porto Rico sweetpotatoes, 1943*

[Results after 4 months. Flavor ratings: 1, Excellent; 2, good; 3, fair; 4, poor; 5, very poor]

Conditions of exposure		Roots decayed when exposed for indicated period after being cured or harvested ¹					Flavor rating when roots were exposed for indicated period after being cured or harvested ¹				
Temperature (° F.)	Duration	Cured (0 day)	Noncured				Cured (0 day)	Noncured			
			0 day	30 days	60 days	90 days		0 day	30 days	60 days	90 days
	<i>Days</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>	<i>Pct.</i>					
57.9 ²	0	3.0	8.2	8.2	8.2	8.2	1.1	1.5	1.5	1.5	1.5
32.....	2	5.6	5.5	5.1	6.9	5.7	2.8	3.4	2.9	1.7	1.2
32.....	4	1.5	10.2	5.2	3.4	7.4	4.2	3.7	2.1	2.5	1.2
40.....	4	1.6	13.0	8.1	8.0	7.3	2.1	3.2	1.8	1.1	1.6
40.....	7	2.2	13.5	10.8	7.0	9.7	1.9	3.2	1.8	1.7	1.7
50.....	10	3.2	19.8	10.8	2.7	3.9	1.8	2.9	1.3	1.5	1.4
50.....	21	3.8	50.1	7.9	4.6	7.9	2.1	2.1	1.5	1.8	1.8

¹ Difference required for significance between treatments: For decay, 8.4 percent; for flavor ratings, 1.2.

² Not subjected to low temperature; stored in a sweetpotato storage house continuously at 50° to 74° (average 57.9°).

EXPOSURES DELAYED AFTER HARVESTING

The partial avoidance of chilling injury by curing freshly harvested sweetpotatoes suggested the desirability of determining the effects of subjecting sweetpotatoes to low temperatures at various periods after harvest. Accordingly cured and noncured roots were subjected to the exposures listed in table 3 immediately after being harvested or cured. In addition 30, 60, and 90 days after harvest noncured sweetpotatoes were subjected to the same exposures. Between harvest and exposure to low temperatures, as well as between exposure and examination, the sweetpotatoes were stored in an electrically heated sweetpotato storage house in which the thermostat was set at 50° F., so that the temperature was not allowed to go below this point and much of the time it was 60° or above, since the temperature in this room averaged 57.9° during the storage period. These sweetpotatoes were held in storage for 4 months after harvest.

It is evident that a significantly higher percentage of noncured sweetpotatoes subjected to a temperature of 50° F. for 10 days

or longer immediately after harvest than of comparable sweetpotatoes not so exposed were decayed. Either curing or delaying the exposure for 30 days or longer prevented this increased decay. The flavor of freshly harvested sweetpotatoes, when subjected to nearly all of the low temperatures, was adversely affected. Either curing or a delay of 30 days or longer between harvest and subjecting the roots to low temperature was effective in reducing chilling injury.

The noncured sweetpotatoes were held in the 50° F. minimum temperature storage room during the period between harvesting on October 23 and storing. For the first 30 days after harvesting the temperature in this room averaged 62° and the relative humidity 79 percent. It is probable that the same physiological changes occurred, although at a slower rate, during this period as occurred in curing, especially upon the several occasions when the temperature was near the top of the range (51° to 79°). These changes were effective in preventing most of the injurious effects of subsequent exposure to low temperatures, except the lowest and most prolonged.

STORAGE AT CONSTANT TEMPERATURES

In two different years two baskets of three lots (carefully, ordinarily, and roughly handled) were stored for 4 to 4½ months at thermostatically controlled, constant temperatures of 60°, 55°, and 50° F. One basket that had had each treatment was cured and one was not. As a check, comparable sweetpotatoes were held in a sweetpotato storage room in which the temperature was not allowed to go below 50° and was higher for much of the time, averaging 57.8°. The results are given in table 4. There was practically no difference in decay of cured sweetpotatoes stored at the different temperatures within the range of 50° to 60° (fig. 2). With noncured sweetpotatoes at 50° there was practically complete loss from decay. Decay was somewhat less in the lots stored at 55° and still less in those at 60°, but even at this temperature it was significantly higher than in sweetpotatoes stored in a storage house in which the average temperature was 57.8°. Apparently the time that the temperature was higher than 60°, especially earlier in the season, permitted physiological changes that prevented chilling injury even when the temperature approached 50° in the storage room.

Although the cured sweetpotatoes stored at 50° F. did not have significantly more decay than comparable sweetpotatoes stored at an average temperature of 57.8° in a sweetpotato storage room, their culinary quality was adversely affected.

TABLE 4.—Effect of temperature of storage for 4 to 4½ months on the decay of cured and noncured Porto Rico sweetpotatoes, 1942 and 1943

Storage temperature (° F.)	Roots decayed ¹	
	Cured	Noncured
	Percent	Percent
57.8 ²	19.5	20.9
60.....	22.9	42.8
55.....	19.2	65.2
50.....	23.9	99.6

¹ Difference required for significance between treatments, 19.0 percent.

² Sweetpotato storage room with thermostat set to keep temperature from going lower than 50° (range 50° to 74°).

STORAGE AT MINIMUM
TEMPERATURES OF
50° AND 55° F.

In order to determine the relative merits of preventing temperatures for the storage of sweetpotatoes from falling below 50° and 55° F., three baskets of cured and three baskets of noncured sweetpotatoes were stored at each of these minimum temperatures for 4 to 4½ months in each of three seasons. They were stored in rooms in a sweetpotato storage house in which the thermostats were set to prevent temperatures from dropping below the desired minimum. The temperatures which prevailed in the room fluctuated with the outside temperatures and averaged 57.2° in the room set for 50° and 59.9° in the 55° room.

One basket was carefully handled, one received ordinary handling, and one was handled roughly. Decay, quality, and loss in weight were practically identical under these two storage conditions, indicating that under climatic conditions such as prevail in the vicinity of Meridian, Miss., it will probably be satisfactory to set the thermostat at 50°, because ordinarily the temperature average will be enough higher to prevent chilling injury. Farther north, where inside temperature probably would be closer to the minimum thermostat settings for a longer period than prevailed in these experiments, it is possible that a setting slightly higher than 50° might be desirable.

These results are of especial importance in electrically heated storage houses because of the saving of electricity involved by permitting the temperature to drop to 50° F. instead of 55°. However, the results are also applicable to storage houses heated by other methods, as only sufficient heat to keep the temperature from dropping below 50° is necessary, and a saving of fuel and labor results.

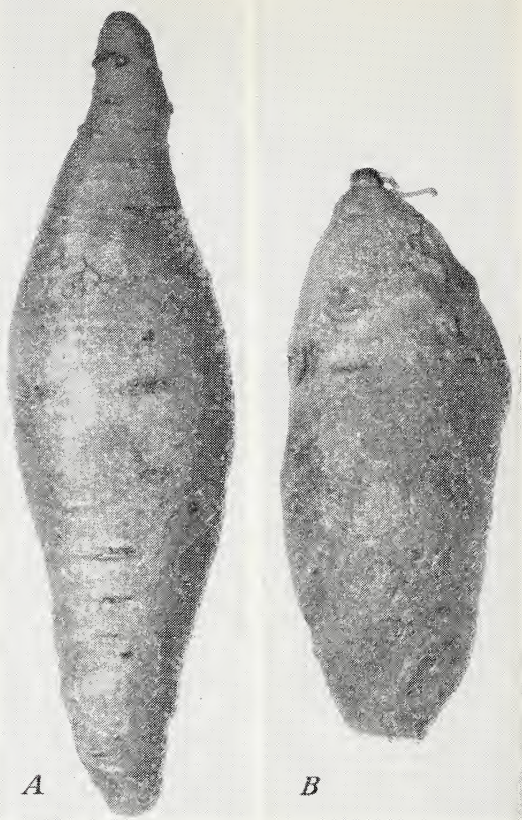


FIGURE 2.—Sweetpotatoes stored at 50° F. for 4½ months: Cured (A) and noncured (B). Note that the noncured root was almost completely decayed.

